Time Domain Impedance Spectroscopy for Probing the Potential Dependent Termination of the Silicon (100) Surface in Aqueous KOH

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Due to its anisotropic etching properties [1], concentrated aqueous KOH is a widely used etchant in the fabrication of micromachined silicon devices. Although potential induced changes of the surface termination are commonly utilised as an etch stop technique for device fabrication [2,3], the surface termination of silicon in KOH close to the open circuit potential is still highly speculative.

In-situ infrared spectroscopy (FTIR) and time domain impedance spectroscopy were used to probe the surface termination of silicon (100) in contact with aqueous potassium hydroxide. The latter technique consisted in applying a 20 kHz square wave modulation and carrying out a Laplace transform analysis of the current. This allowed time-dependent measurements of the space charge capacitance with a time resolution better than 1ms. The time domain impedance spectroscopy method is a powerful tool to probe non-linear coupling between surface and bulk semiconductor properties.

Since the space charge capacitance is closely related to the potential distribution within the semiconductor, these measurements can be used to probe the interfacial potential distribution. A transient behaviour of the space charge capacitance, with a time constant of about 1 s, was observed following a potential step (Figure 1). This behaviour gave rise to a time dependent deviation from the Mott-Schottky linear dependence (Figure 2). Fermi level pinning is observed close to the etching potential and this is related to the nature of the surface termination. The abrupt change is slope in the Mott-Schottky plot is attributed to a potential dependent replacement of surface hydrogen termination by strongly polarised oxide bridges between surface silicon atoms (Figure 3).

On n-silicon (100), the time domain technique allowed space charge capacitance measurements that were sufficiently short to obviate the surface passivation, which was previously found to impede measurements at high anodic potentials [4]. Therefore, space charge capacitance measurements could be extended far into the passive potential range, which allowed the experimental determination of a flatband potential of -0.85 V vs. SCE.

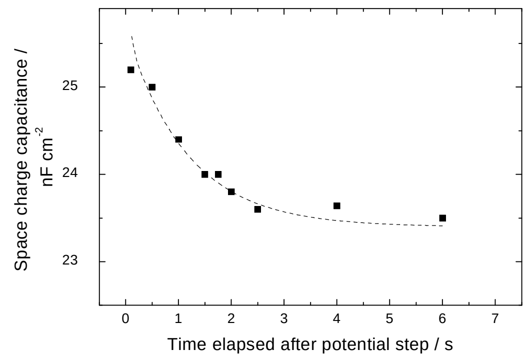

Figure 1: Time-resolved space charge capacitance of p-silicon (100) in 6 M KOH following a potential step. (Initial potential: -2.0 V, step potential: -0.96 V).

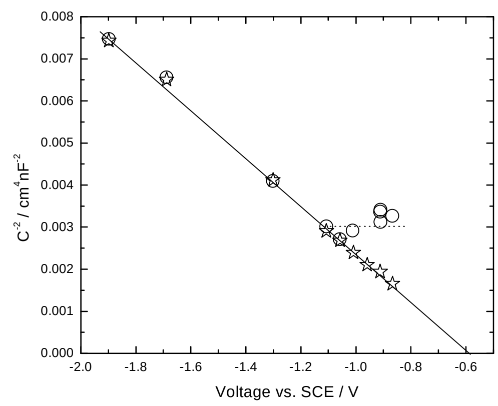

Figure 2: Time-resolved Mott-Schottky plot of p-silicon (100) in contact with 6.1 M KOH. The space charge capacitance was measured at 200 ms (stars) and 6 s (circles), respectively after the potential step. The initial potential was -2.0 V.

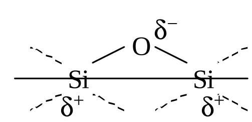

Figure 3. Proposed surface termination at potentials positive to the open circuit etching potential.

References

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